Testing Global Warming Theory With Satellite Passive Microwave Observations

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Satellite passive microwave data contain valuable information on the workings of Earth's climate system. Specifically, temperature and water vapor data are being utilized to better understand how the climate system responds to natural forcings so that better estimates of global warming can be made. These satellite data are having increasing impacts in the science and policymaking communities through new climate diagnostic studies and an 18-year record of global temperatures.

The microwave sounding units (MSU) on the National Oceanic and Atmospheric Administration's TIROS-N series of polar-orbiting satellites are supporting the only global temperature monitoring effort in existence. An 18-year record (1979 to present) of global lower tropospheric and lower stratospheric temperatures continues to be updated on a monthly basis (fig. 153). Careful intercalibration of a total of eight separate satellites' instruments was necessary to achieve a data record having sufficient precision to calculate long-term trends in global temperatures. This record has been independently validated with radiosonde (weather balloon) data which has revealed excellent agreement. This validation has now been extended through 1994. Several types of temperature data sets have been developed and made available to the global research community, and have formed the basis for numerous published research studies. For example, the seasonal and geographical distribution of lower stratospheric cooling has been linked to total ozone mapping spectrometer (TOMS) trends in total column ozone, thus providing independent validation of global ozone depletion. The development of the method, first published by R. Spencer of NASA and J.R. Christy of the University of Alabama in Huntsville in 1979, was recognized in January 1996 with the American Meteorological Society's (AMS) Special Award. This award was the first given by the AMS for the development of a satellite method for monitoring climate fluctuations.

The global temperature record is often cited by skeptics of global warming because it has not yet indicated a warming trend since 1979. Because the surface thermometer data have indicated a small global warming trend for the same period, several groups are now actively involved in understanding why the two data sets do not agree. Based upon our recent research, it appears that the satellite measurements, which represent a deep layer of the atmosphere, are indicating that temperature fluctuations can change with height in the atmosphere. As a result, decadal trends of surface thermometer data probably can not be expected to agree with the satellite trends to better than about 0.1 to 0.2 °C per decade. This is contrary to expectations of many climate researchers, though there has not been any observational basis for that expectation, only theoretical. Because computerized general circulation models (GCM's) suggest that any warming will increase in magnitude with height, combined with the known tendency for surface temperature data to be susceptible to localized effects, we believe the satellite data will be increasingly relied upon for first signs of global warming due to its larger signal-to-noise ratio. Indeed, new analytical techniques we are utilizing to retrieve temperature trends as a function of

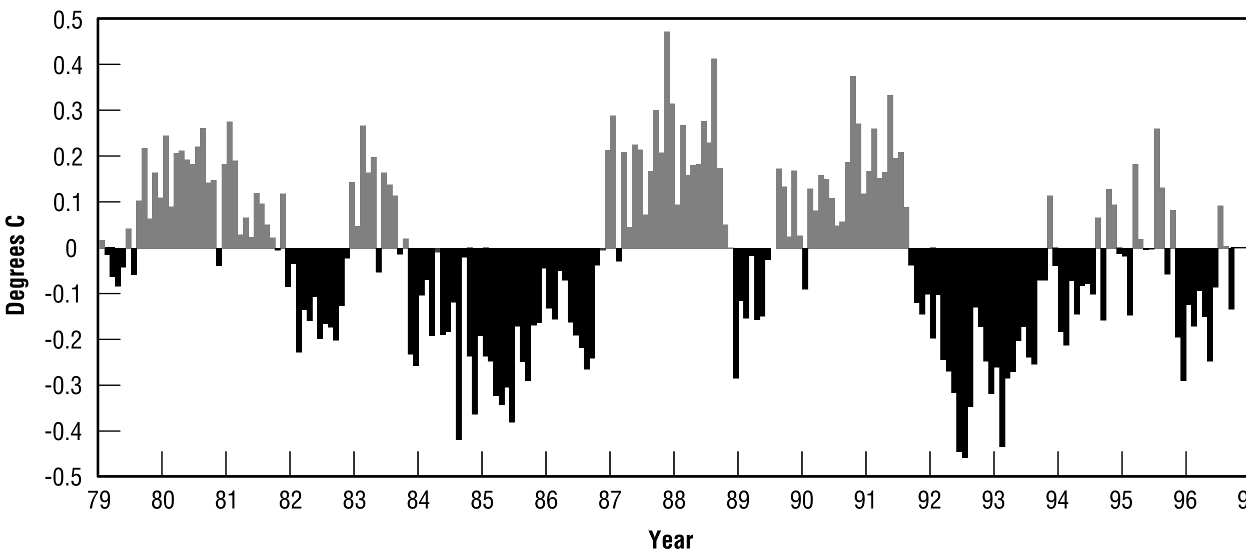

FIGURE 153.—Global lower tropospheric temperatures (1979 through 1996).

height are suggesting that the global upper troposphere has warmed substantially in the last 18 years. But, combined with the lower tropospheric cooling trend indicated in the same data, it now appears that the climate system is more complex in its behavior than was previously appreciated. This should not be too surprising, though, since moist convective processes (clouds and rainfall) that transport excess surface heat to high in the troposphere, are not well represented in GCM's.

With the approaching implementation of the United Nations framework convention on climate change (FCCC), the satellite temperatures will likely be central in the argument against hasty action to curb emissions of carbon dioxide, the leading contributor to the enhanced greenhouse effect. Because protocols implemented under the FCCC treaty could have huge economic consequences, the satellite temperature monitoring effort is having a direct impact on the economies of the United States and the world.

Central to global warming theory is the existence of "positive water vapor feedback." This is a process wherein the small amount of warming initiated by increasing levels of carbon dioxide in our atmosphere is amplified by increasing levels of water vapor (the Earth's main greenhouse gas) that is expected to occur in response to the initial warming. This sets up a positive feedback loop which results in water vapor feedback being responsible for most of the warming in future projections of global warming. While this feedback is likely to be positive in the turbulent boundary layer, it is much less certain whether it exists at all in the free troposphere above the boundary layer. We are utilizing new observations from the water vapor sounder (SSM/T–2) instruments that flew on the defense meteorological satellite program's (DMSP) F11 and F12 satellites. We have assembled the only complete record of SSM/T–2 data since 1993, and have focused on the relationship between sea surface warming and free tropospheric humidity in the tropics. During the 1993 to 95 period, a warming occurred as the Earth emerged from the cooling effects of the 1991 eruption of the Mt. Pinatubo volcano. During this warming we found no evidence of positive water vapor feedback in the tropical free troposphere. However, this might not necessarily represent the climate system's response to increasing levels of man-made greenhouse gases, and so additional years of data will be required to determine whether water vapor feedback varies between different types of climate fluctuations. An interesting spinoff of the water vapor work has been the discovery that the tropical free troposphere is, for the most part, extremely dry (Spencer and Braswell, 1996). We find peaks in the daily frequency distribution of tropical gridpoint relative humidity between 5 and 10 percent. This new finding will have important implications for how GCM's control humidity, since small fluctuations in humidity at such dry levels can have huge impacts on outgoing longwave radiation, the type of radiation central to global warming theory.

The satellite passive microwave observations of deep-layer atmospheric temperature and water vapor will continue to have a large impact on our understanding of how the Earth's climate system operates. This understanding will lead to improvements in GCM's and in their predictions of future global warming.

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